RECENT ADVANCES IN TELEVISION WAVEFORM MONITORING

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Quantitative measurement of picture quality on an in-service basis is now within the state-of-the-art and will, in the near future, permit significant improvement in picture quality on television networks. To this end, the National Television Committee has adopted standards for a set of test signals to be transmitted during the vertical blanking interval.

At the 1964 Convention of the NAB, Mr. S.C. Jenkins read a paper detailing the history of Vertical Interval Test Signals, which will be widely known as VITS. He also described the work of the National Television Committee which established two periods for test signal transmission. The interim period was to acquaint personnel in the industry with the signals that were available from the available equipment and the "Optimum Plan Signal" which was to be implemented on 1 February 1965 in which somewhat more sophisticated signals would be introduced. This event has been postponed. As mentioned by Mr. Jenkins, a major problem in the VITS program is that the entire usefulness of the VITS depends upon the availability of suitable waveform monitors capable of displaying these signals in such a way that accurate measurements can be made from their observation. At least one manufacturer anticipated the requirements for VITS monitoring and a new monitor, fully compatible with the requirements of VITS monitoring, is currently available.

Paragraph 3.368 of the FCC Rules, permitted test signals on lines 18, 19 and 20 of the vertical blanking pulse and also permitted signals during the last 12 μsec of line 17. Line 21 is to remain blank. Vertical blanking must include line 21. Thus, a minimum of one line above the top of the picture remains blank as a guard band. As line 20 is reserved for other purposes, our discussion focuses upon lines 18 and 19 of both fields. The VITS will not be observed on properly adjusted receivers, being above the mask opening, but they can be observed by rolling the picture with the vertical hold control.

In the interim signal, line 18 of both fields - the multiburst signal - is displayed continuously. Line 19 of both fields alternately displays the $\sin^2$ pulse and bar for 2-1/2 minutes and then the modulated stairstep for 2-1/2 minutes. As both fields carry the same signals there is no requirement for a field selector in waveform monitors. A line selector is required.

In the optimum signal different signals are to be transmitted on each line of <u>each</u> field. Thus, four test signals will be continuously transmitted. With suitable waveform monitors it will be possible to select the test signals on field ONE or field TWO at will.

Field ONE, line 18 will have the usual multiburst signal which will provide useful spot checks of frequency response. The frequencies are 0.5, 1.5, 2.0, 3.6 and 4.2 mc. Thus, the waveform monitor must have a FLAT frequency response to 5 mc, within ±0.1 db (±1%), which is quite readable on 5" crt graticules and can be maintained over long periods of operation without recalibration.

Also required is a LOW PASS frequency response rolling off at about 100 kc with more than 16 db attenuation at 500 kc and negligible response above 500 kc to permit checking for rectification of any of the burst frequencies by observing axis shift of the pedestal level.

Black set-up level and white reference level signals are included in the multiburst signal. The position of the white reference signal may indicate the test signal origination point.

Line 19 of field ONE contains the $\sin^2$ pulse and bar display about which we shall have much to say. It tells us about the transient response of our transmission system. Ringing and smear can be measured in terms which can be related to the severity of picture degradation.

Line 18 of field TWO will contain a color test signal to be specified at a later date. At least one network has experimented with special color bar displays transmitted during the vertical interval.

On line 19 of field TWO, the linearity stairstep with subcarrier modulation will be transmitted.

The ten step staircase signal can be observed for low frequency nonlinearity, white stretching or compression, etc., by means of the IEEE Rolloff which will remove the subcarrier modulation and most "white noise." Differential gain can be accurately measured with a HIGH PASS filter with response peaked broadly at 3.6 mc and adequate gain reserve to display 100 IEEE units vertical deflection of the subcarrier signal. The optimum signal is to have 20 IEEE units of subcarrier modulation. Ten units of subcarrier would provide better measurement accuracy in noise and free signals, but 20 units is necessary considering noise levels observed in practice. High frequency rolloff might cause significant gain reduction at 3.6 mc and adequate gain reserve is considered necessary.

Color transmission requires that differential gain distortion be held to very low limits. The modulated stairstep test signal can measure this distortion very easily and directly. Differential phase distortion, which is equally important in color TV, cannot be measured on waveform monitors because they lack the phase demodulator and subcarrier regenerator circuits necessary to make this test. However, at least one vectorscope, which is widely used here and abroad, can make differential phase measurements of modulated starstep signals during color transmissions.

Network experience has indicated that it is highly desirable to have frequency lock between the color subcarrier and the subcarrier on the linearity stairstep of the VITS. This eliminates beats which could be troublesome on some color receivers. This fact enables the vectorscope's subcarrier regenerator to lock the transmitted color burst and phase demonulate the high frequency subcarrier on line 19.

During monochrome transmission the color burst is, of course, missing and differential phase distortion cannot be measured because the subcarrier

regenerator cannot phase lock to the subcarrier. This is unfortunate because it might permit a better selection of signal routing over telephone company facilities prior to color transmissions. (The telephone company makes differential phase tests of its facilities on an out-of service basis.)

A vectorscope can also measure differential gain distortion. Some form of line selector is required on vectorscopes as well as on waveform monitors to see the VITS effectively. The Tektronix Type 526 has a line selector feature called Interfield Signal Key which permits observation of this test signal without video clutter.

We have lightly touched upon the $\sin^2$ pulse and bar test on line 19 of field ONE. This is surely the most sophisticated test in the VITS. While every engineer is thoroughly familiar with the multiburst signal through years of usage, the $\sin^2$ technique is much less familiar in North America. It was developed in Europe and has been widely used for some years.

The mathematical implications of the name will cloud the issue rather than describe it in a meaningful manner to the majority of engineering personnel. Skirting the mathematical, this signal approximates the waveform of a camera signal as the scanning beam crosses over a very sharp black-white transition. Were the resolution of the camera infinite and the bandwidth of the amplifiers infinite, such a transition would be a step function having zero risetime and step-shaped transitions.

The practical camera generates a signal closely corresponding to the $\sin^2$ signal. Its frequency spectrum is limited. 99% of all its energy is contained within a bandwidth equal to the reciprocal of the pulse width measured between 50% points, and 50% of its energy is contained in half this much bandwidth; i.e., 0.125 µsec pulse, 50% down at 4 mc, 99% down at 8 mc.

The limited bandwidth of TV systems invalidates the step function transition (squarewave) testing because any system which has a rolloff characteristic much steeper than Gaussian will exhibit ringing when excited by a "step function" type of signal. Camera signals, not being step functions, do not cause this ringing. Obviously it would be ideal to use something approximating the camera signal as a test signal. Only improperly operating systems will "ring" when excited by the $\sin^2$ signal. Such systems will exhibit "ringing" when handling video signals and picture degradation will be observed. (The $\sin^2$ tests do not duplicate the multiburst test, which is a steady state frequency response only.)

The phase response of the system is of importance equal to that of its frequency response. Together they tell the story. Phase linearity is the requirement that all frequencies transmitted by the system shall suffer phase shift directly proportional to frequency. This condition is met only when the time delay through the system is the same for all frequencies. There are many circuits used in the TV system which do not have ideal phase linearity even when they are non-frequency discriminating, i.e., flat. Long coaxial cables, aperture correctors and vestigial sideband filters are examples of phase distortion causing elements in TV systems.

Phase distortion is evidenced by a lack of symmetry around the $\sin^2$ pulse. Ringing preceding the pulse, but not following, indicates that the high frequencies are suffering too little delay (leading highs.) Ringing after the pulse denotes excessive high frequency delay (trailing highs).

Amplitude response near the cutoff frequency relative to midband frequencies is indicated by the relative amplitude of the pulse to the bar signal. The bar, of course, represents mid frequencies. Tilt, positive or negative, of the bar signal indicates the critical condition of non-uniform gain at the mid frequencies. This gives rise to streaking or smear in the picture. Interestingly, the same percentage of high frequency ringing and mid-frequency tilt do not cause the same amount of picture degradation. Mid-frequency aberrations cause severe distortion, evident on all receivers of course, while ringing near 4 mc might go unnoticed on many receivers. In fact, some overshoot near the upper-frequency cutoff of receivers generally adds some crispness to the picture. Picture quality always suffers from mid-band distortions which are evidenced by distortion in the bar waveform.

Early work with this sort of signal indicated that the signal degradation, as measured on the waveform monitor, could be correlated with the severity of picture degradation. This led to the development, initially by European TV authorities, of the concept of K FACTOR TESTS.

By a series of subjective viewer reaction tests, high quality signals were aberrated in a variety of ways with viewers rating the quality of the pictures. Out of this has come data which relates the relative degradation of the picture to measured amounts of all the distortions observed using the $\sin^2$ pulse and bar technique. The K (for quality constant) factor establishes arbitrary quality standards for TV signals in terms of picture degradation from slight to severe.

Use of the K factor system requires special graticules with limit lines scribed thereon. Typical K factor graticules are ruled for two values of K. If the $\sin^2$ pulse and bar fit between the inner and outer limits, it is between two and four percent. If the waveform remains within the innermost lines, it is obviously better than two percent. If we cannot get the entire waveform within the outer limit lines, we must conclude that we have something worse than four percent K factor signal quality.

A five percent factor distortion is detectable by skilled observers. Three percent K factor is not noticeable. A K factor of one-half percent can be produced by 0.05 db gain differences at low frequencies while 0.3 db gain differences are at high frequencies.

Sin^2 testing is done with two different pulse widths, depending upon the application. Tests of studio equipment flat to 8 mc are conducted with 0.125 µsec HAD pulses and overall TV plants and links with 0.25 µsec HAD pulses which have frequency spectrum to 4 mc. The $\sin^2$ pulse in the VIT is 0.125 µsec as a more sensitive test for ringing.

The waveform monitor should have two sweep rates 2:1 different so that one graticule will serve for both pulse widths. Several different K factor scales will be required, even so, for complete testing. These should become readily available when standards are established.

Operational details will be worked out by the several networks and the telephone company. An important result is that now means are at hand to establish the quality of the TV signal as it is delivered by the telephone company to the individual stations along the network.

The $\sin^2$ pulse adopted by the NTC is 0.125 μsec wide (measured between 50% points). This pulse has a frequency spectrum extending to 8 mc. It is down 50% at 4 mc. It will provide a very sensitive test for "ringing." However, it poses problems using the K factor rating system because the intercity facilities of the telephone company are not flat to 8 mc.

I have touched only slightly upon the subject of $\sin^2$ testing. The bibliography lists several detailed articles.

The VITS provide capability for in-service testing with nearly every test signal commonly used. To complete our survey of VITS we should consider its limitations.

Compared with full-field testing, which is possible only on an out-of-service basis, VITS can do most of the industry tests on in-service basis. It cannot do the white window test for low-frequency equalization response measurements because this signal occupies a full field in order to test down to the lowest frequencies in the video signal.

The linearity signal in full field testing is normally used with a range of average picture level from 10-90% corresponding to testing system performance over its entire dynamic range from bright to dim scenes. Unfortunately a great many amplifiers in the TV system are AC coupled and their dynamic range must be nearly twice what would be required were the input black level stabilized at a fixed value. Black picture elements in a predominately white scene swing to the negative limit of the dynamic range of amplifiers, while white elements in dark scenes drive the amplifiers to the positive limit of their dynamic range. To probe the entire dynamic range, the average picture level of the video signal is varied and results compared for any differences.

VITS will probe various parts of the system's dynamic range as the picture's accompanying average brightness varies. This condition is beyond the engineer's control. However, he can observe all four VITS at any time and it seems reasonable that he can check VITS on his waveform monitor while observing the brightness of his picture monitor. Thus, he can discern whether the test signals change significantly with changes in average picture level.

Television waveform monitor development has paced the development in sophisticated testing techniques. Accuracy has been steadily improving to where 1% measurements of amplitude, 1% accurate frequency response to 5 mc, derated to 3% at 8 mc, and 1% measurements of linearity are readily obtainable.

Modern equipment is capable of these accuracies, not only when new but will remain in calibration over very long periods, over temperature ranges commonly encountered, and quite independent of power line voltage.

Graticule parallax can be entirely eliminated as a source of error by inscribing the graticule within the crt. Parallax errors can amount to ±3% with modern, flat-faced crt(s).

Observing the $\sin^2$ pulse requires a line-selector equipped instrument. To observe this signal, suitably magnified to afford observation of ringing, the crt must have a brightness capability in excess of 400 foot lamberts, which is far beyond the performance capabilities of most laboratory grade oscilloscopes. However, it is not beyond the state-of-the-art today. Such high brightness is needed only when using the Line Selector. Besides the inconvenience to the operator to have to readjust the Intensity control when switching to or from VITS, accidentally turning it up full would damage the crt, burning it out if there was a total sweep failure. This problem has been neatly overcome recently. A low duty cycle pulse from the line selector is ac coupled to the crt grid to automatically boost brightness when needed. DC coupling of the retrace blanking is also provided.

When the optimum test signal is placed in service, each field will carry different test signals. It will then be quite desirable to have a field selector circuit which is immune to noise and interference to maintain the selected field in view.

To observe the VITS, the waveform monitor must be equipped with an accurate dc restorer. Simple diode clamping of the video signal will not be adequate. Best possible linearity and gain stability can be achieved by direct coupled vertical amplifiers with a feedback loop type of dc restorer. This feedback maintains the signal in the most linear portion of the amplifier's dynamic range independent of changes in average brightness level. Drift in the dc amplifier is eliminated by the feedback action.

Monitoring of VITS throughout the individual station's plant from net feed to transmitter output is necessary in view of the fact that the transmitter is often responsible for many of the distortions which VITS is meant to test. Operators of community TV antenna systems should find that VITS will be a useful tool in determining signal quality they are delivering to their customers.

The Canadian Broadcasting Company plans an interesting variation in VITS testing of their network. They plan to insert VITS on the signal leaving an origination point and gate it out at a distant city along the network -- inserting a new, clean, undistorted VITS for transmission to the next major facility. Thus, their VITS always measures the intercity system. It may not represent the video picture quality at a distant point. The advantage is, of course, that when the VITS shows degradation in transmission quality they know that the trouble lies in the facility directly preceding along the network and remedial action can be very quickly initiated.

It is quite conceivable to think of a fully automated system which would monitor VITS electronically and alert personnel when substandard conditions were detected. Such systems would then automatically report the defect and log the time when service was restored to standard. Some TV authorities (Russian) have experimented with scan converting the VITS and telemetering the output of the scan converter system to the transmission supervisor who could then initiate remedial measures.

VITS will initiate a new era in the quality control of television transmission. These signals will improve the communications between the many station engineers, telephone company operations personnel in television operating center(s) and network headquarters. The expected results -- a higher quality of TV service to the public.

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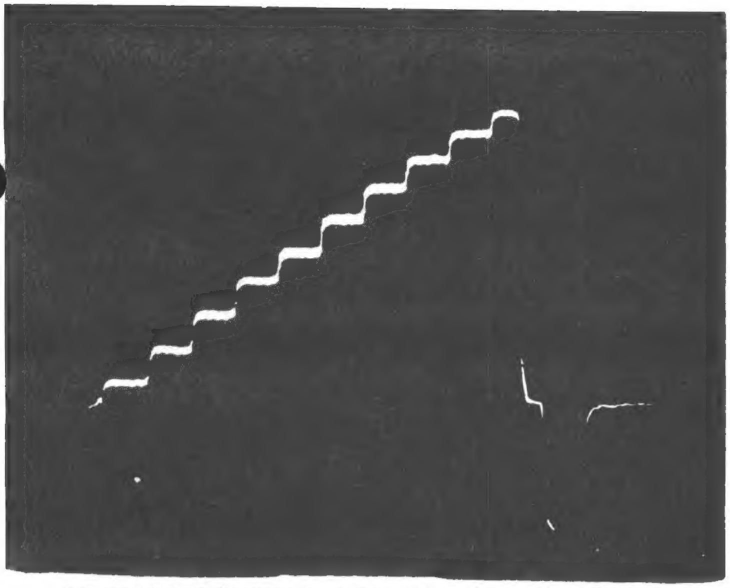
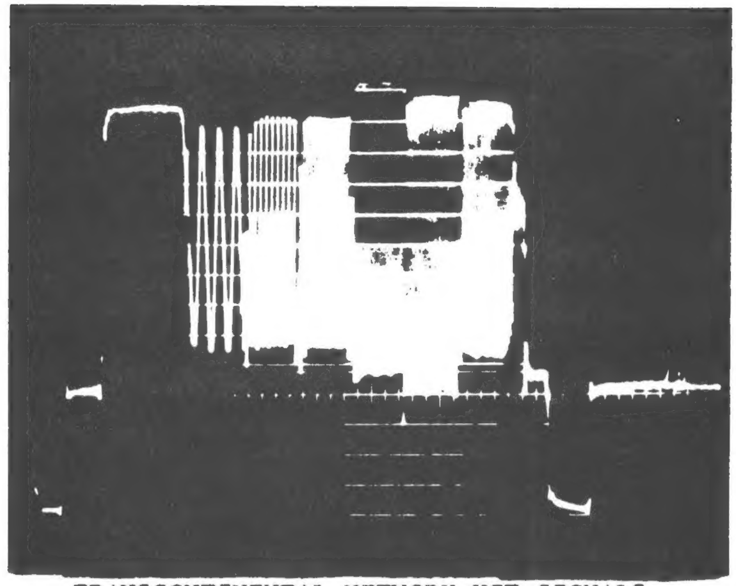
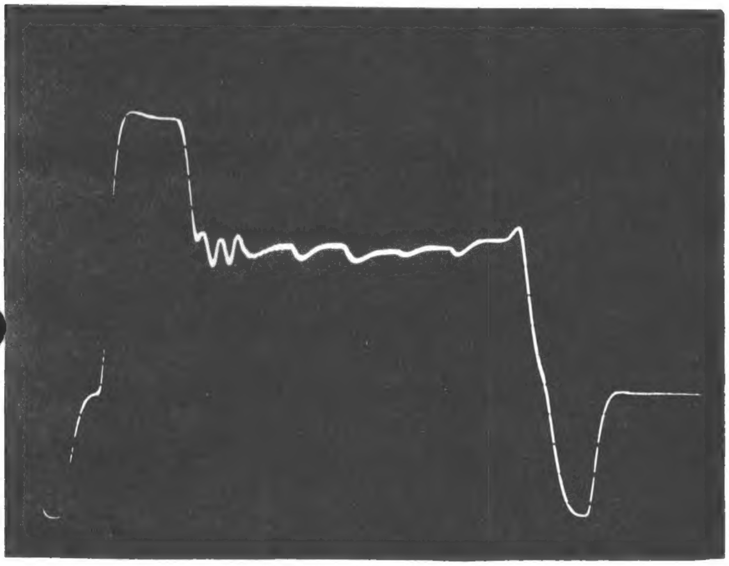


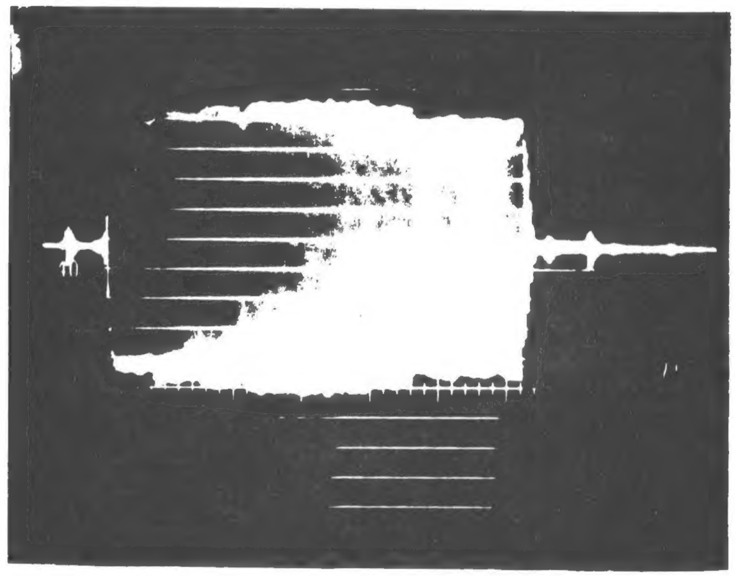
TRANSCONTINENTAL NETWORK VIT SIGNALS
VIEWED THROUGH TRANSMITTER
MULTIBURST FLAT



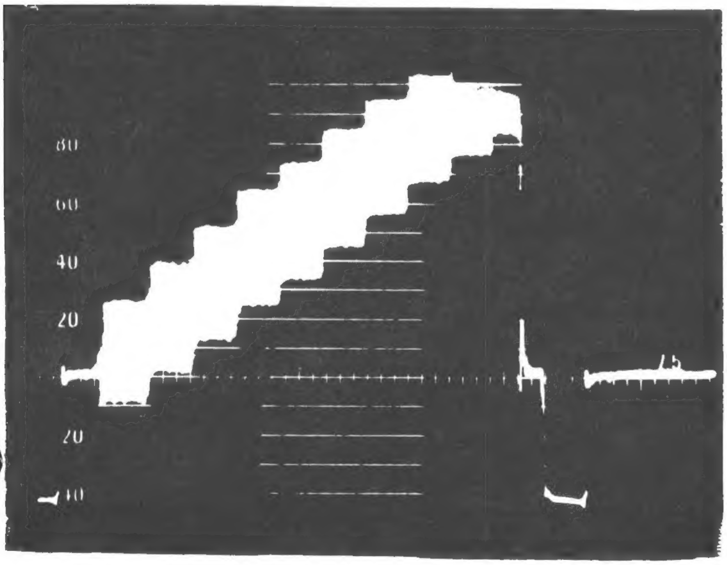
TRANSCONTINENTAL NETWORK VIT SIGNALS
THROUGH TRANSMITTER
MODULATED STAIRSTEP IEEE RESPONSE



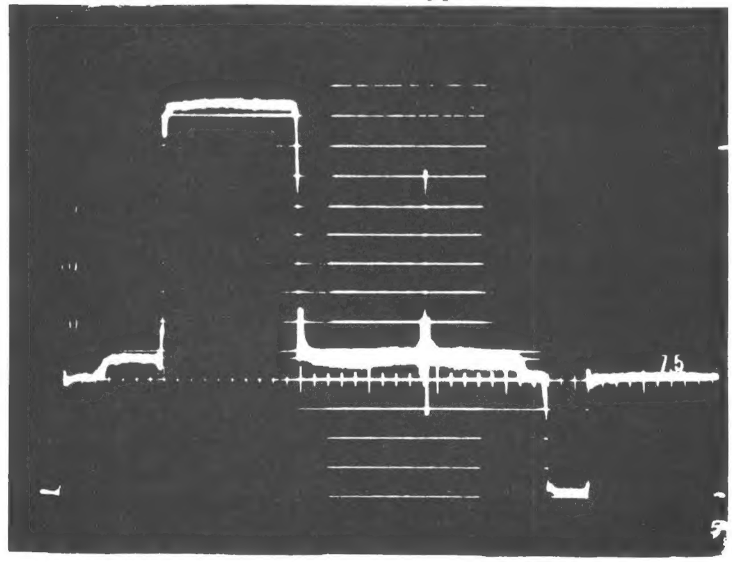
TRANSCONTINENTAL NETWORK VIT SIGNALS
MULTIBURST
LOW PASS RESPONSE



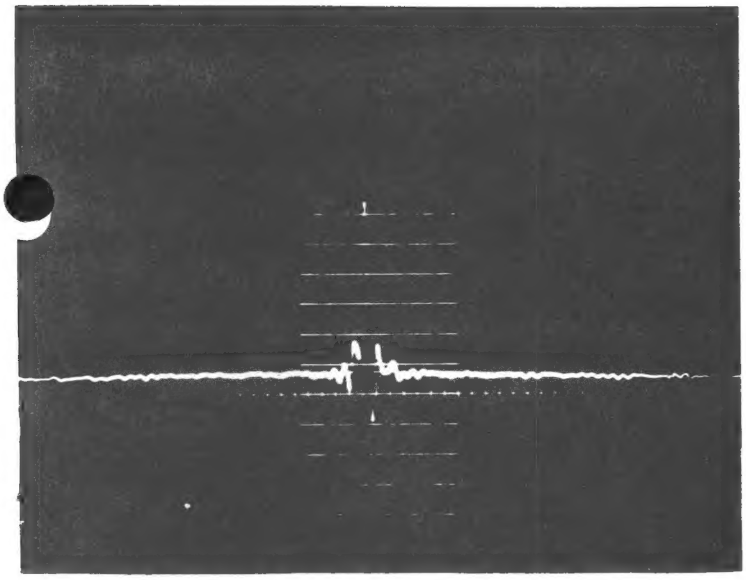
TRANSCONTINENTAL NETWORK VIT SIGNALS
MODULATED STAIRSTEP
HIGH PASS RESPONSE
Gain Increased Approx. 5X



TRANSCONTINENTAL NETWORK VIT SIGNALS
MODULATED STAIRSTEP FLAT RESPONSE



TRANSCONTINENTAL NETWORK VIT SIGNALS
SIN^2 BAR & PULSE



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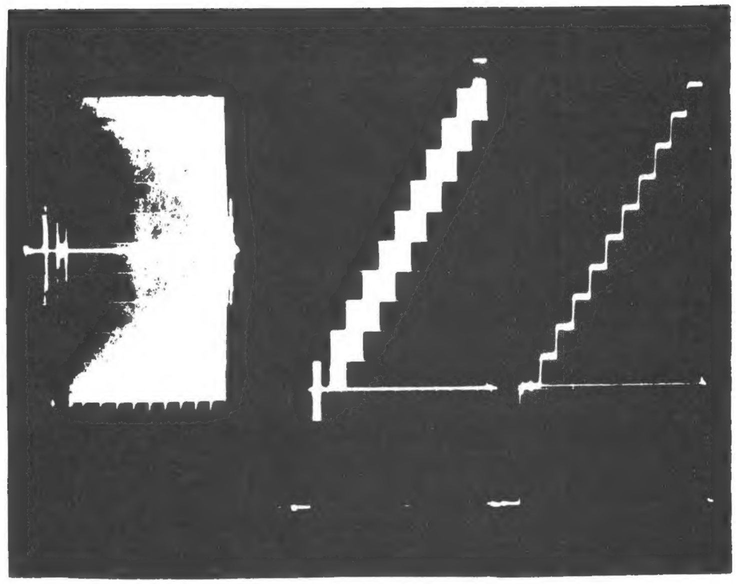
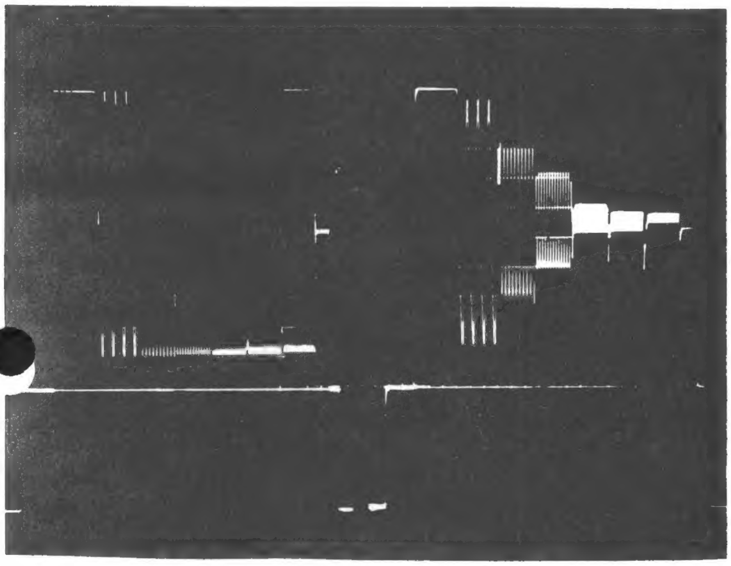
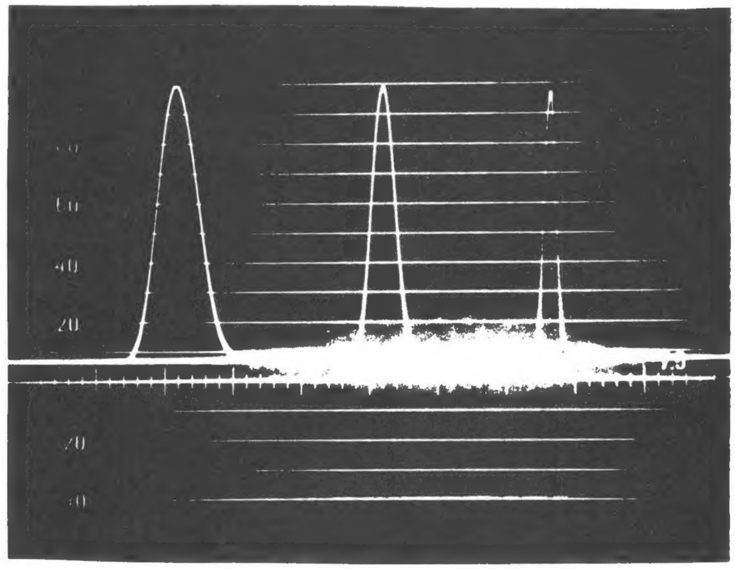
SIN^2 PULSE X5 HORIZ. EXPANSION



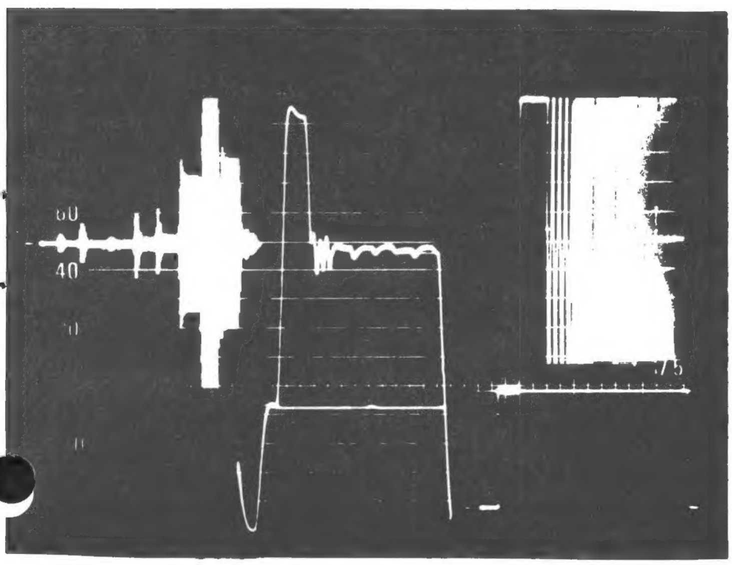
MODULATED STAIRSTEP SIGNAL
HIGH PASS RESPONSE GAIN X5 | FLAT RESPONSE | IEEE RESPONSE



MULTIBURST
FLAT RESPONSE & IEEE RESPONSE
(Double Exposure)



2T, T & 1/2 T SIN^2 PULSES



MULTIBURST
*HIGH PASS | LOW PASS | FLAT RESPONSE
(Triple Exposure)
*See Note

*Note: HIGH PASS response centered at 3.6 mc 400 kc bandpass